Forward hadron calorimeter (FHCal) at MPD NICA

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Forward hadron calorimeter (FHCAL) together with Time Project Chamber (TPC), Time-Of-Flight (TOF), Electromagnetic Calorimeter (Ecal) and Fast Forward Detector (FFD) are basic parts of the MPD experimental setup at NICA, Dubna, Russia. As any heavy-ion experiment the MPD needs to characterize the ion collisions, i.e. to measure the geometry of heavy ions collisions. The main purpose of the FHCAL is to provide an experimental measurement of a heavy-ion collision centrality (impact parameter) and orientation of its reaction plane.

FHCal structure

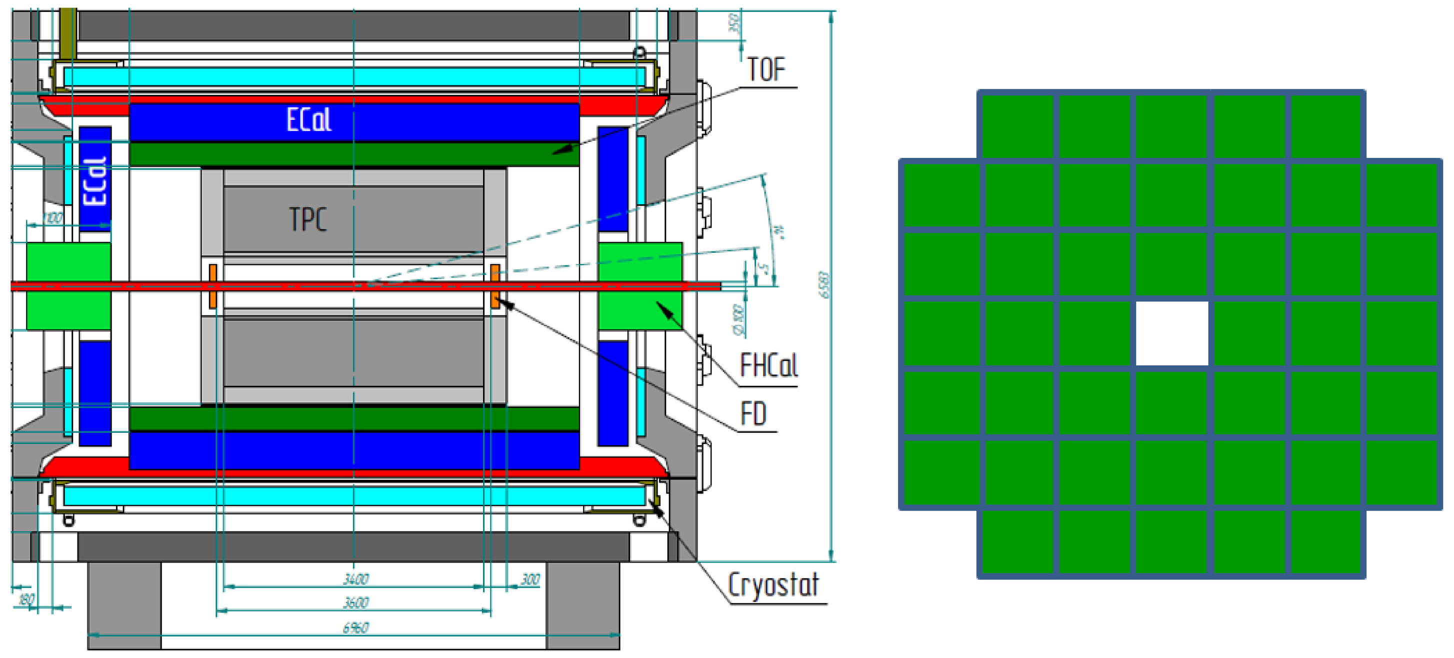

Fig. 1. Left – the side view of the MPD experiment with the FHCal (green). Right – the modular structure of the FHCal.

Fig. 2. Left – view of the FHCal modules. Right – the module structure.

The schematic design of the FHCAL module, the structure of the FHCAL and its position in MPD setup are shown in figure 1. The calorimeter consists of 44 individual modules with the transverse sizes 15x15 cm^2 each. The FHCAL module has 4 interaction lengths and included 42 lead/scintillator sandwiches. The thickness of lead pates and scintillator tiles are 16 mm and 4 mm, respectively, that provides 4:1 compensating ratio. The light in the scintillator tiles is read out by the WLS-fibers embedded in the groves inside the scintillator. Each 6 consecutive WLS-fibers are viewed by a separate photodetectors that ensures the segmentation of the FHCAL module in 7 longitudinal sections [1].

FHCal detects the projectile non-interacting fragments (spectators) from each colliding nucleus to reconstruct the collision geometry, namely, the centrality and the reaction plane orientation. Since the spectators carry the beam momentum, the released in calorimeter energy for a single nucleon is rather low and lies in the range of 1–4.5 GeV depending on the beam energy.

Amplitude parameters of modules for hadron calorimeter at MPD/NICA

The MPD experiment will not provide the muon beam. Therefore, the cosmic muons are to be used for the energy calibration of the calorimeter. There are two options to arrange the cosmic muon trigger. In the first case the outer muon trigger counters can be placed around the calorimeter. The second option is self-triggering mode. All modules were equipped by FEE boards with Hamamatsu photodiodes, initially by MPPC type S12572-010P and then by MPPC type S14160-3010PS. The signals from longitudinal sections of all modules were recorded in case when at least one signal had the amplitude higher of some threshold [2].

In figure 4, the corrected amplitude spectra have prominent peaks, corresponding to the pass length of horizontal muons along the module axis. According to the tests with beam muons, these muon peaks correspond to 5 MeV of deposited energy. As expected, due to the higher PDE and gain the amplitudes for MPPC type S14160-3010PS are factor of 2 higher comparing to that for type S12572-010P.

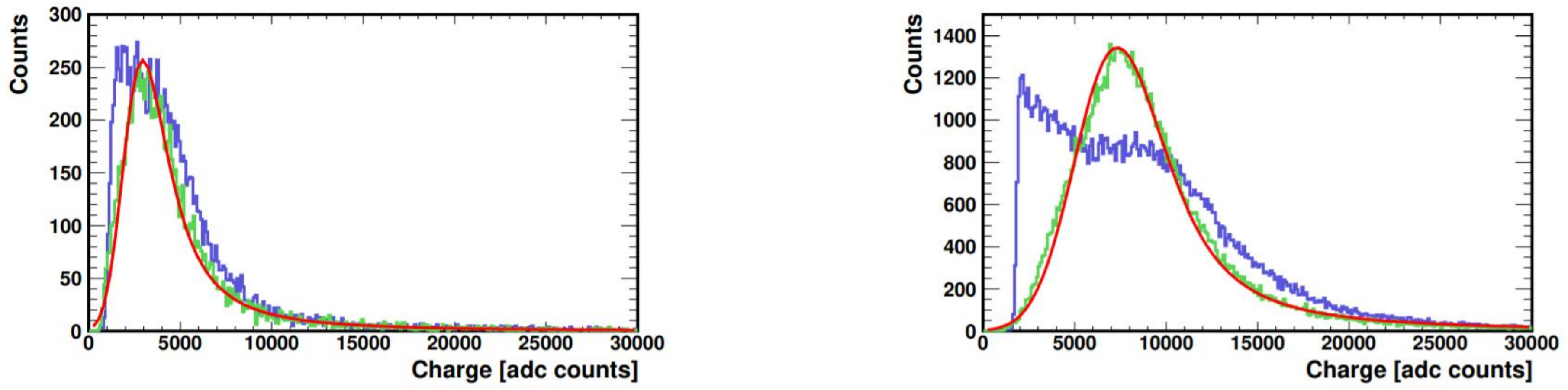

Fig. 4. Amplitude spectra in one longitudinal section of FHCal module for MPPC's type S12572-010P (left) and type S14160-3010PS (right). Blue lines — raw cosmic muon spectra, green lines — spectra corrected for the muon pass lengths in scintillators, red lines — fit of corrected spectra with Landau distribution.

Since the cosmic muons cross the FHCal modules in all directions, the pass lengths in the scintillators and, respectively, energy depositions vary in wide range. The longitudinal segmentation of the modules allows to reconstruct the muon trajectories and to correct the deposited energies according to their pass length.

Using the muon peak position (see figure 4) and of the conversion factor obtained from MPPC amplitude calibration, one can easy calculate the number of photoelectrons produced by minimum ionising particles (MIP's) crossing the modules. Averaged over all tested modules light yield for each longitudinal section is shown in figure 5 for both types of MPPC's. And the average noise estimation is shown in figure 6.

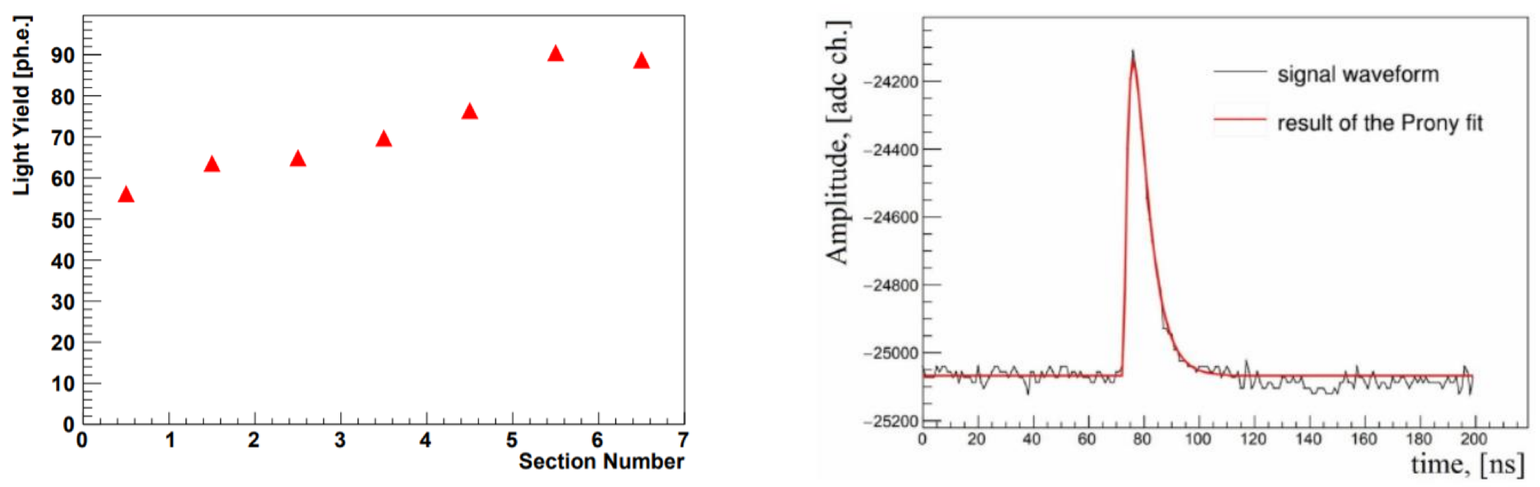

Fig. 5. Light yield in longitudinal sections of FHCal modules measured with MPPC's type S14160-3010PS (left). First step of the evaluation of cosmic muon spectrum, signal fit by Prony least squares method.

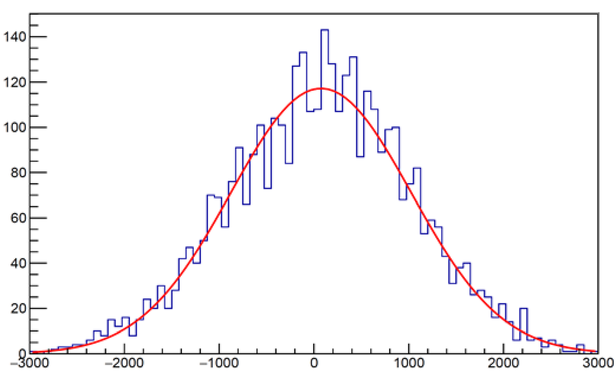

Fig. 6. Noise estimation with muons.

Noise estimation is done by taking two width integration intervals (baselines) of the waveform before the main signal. The two integrals are then counted and one is subtracted from the other. The results obtained: $\sigma_{Noise} = \frac{\sigma_{graph}}{\sqrt{2}} \cong 672\ [ch]$, MIP signal ≈ $7000\ [ch]$,
Noise in MIP: $\cong 0.1\ [MIP]$

By varying the noise level we obtain the following correlation between the energy deposition in the calorimeter and the proton beam energy (Fig.7).

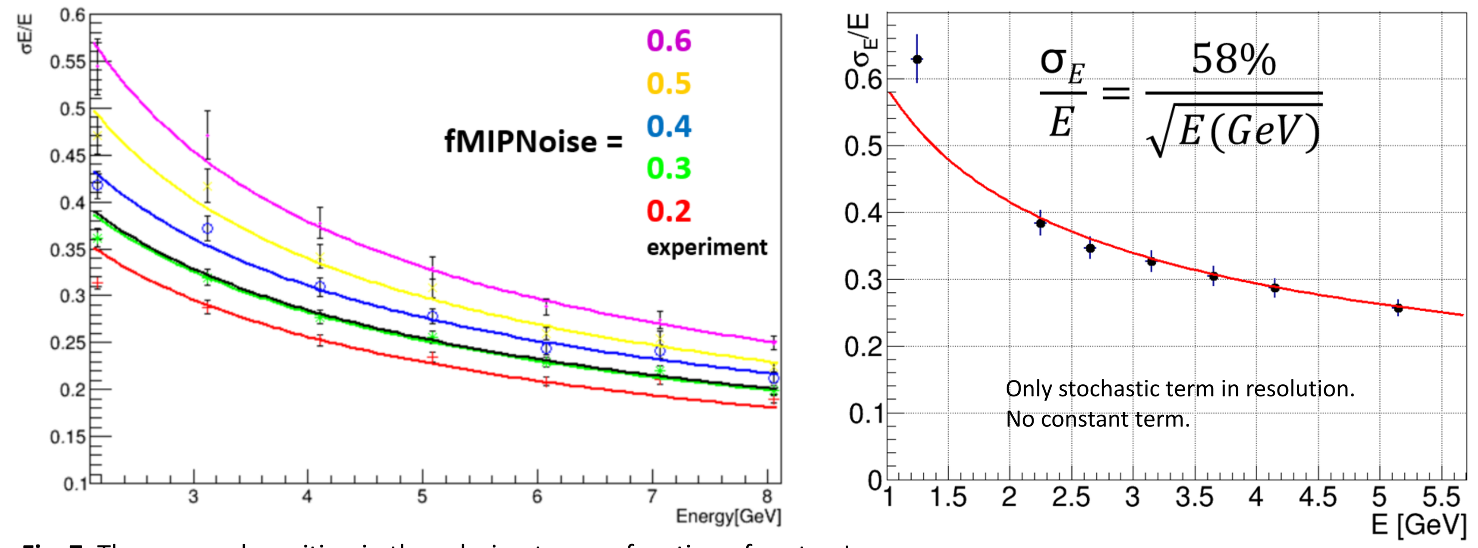

Fig. 7. The energy deposition in the calorimeter as a function of proton beam energy.

Application: centrality determination with FHCal

The FHCal has a modular structure and the deposited energies can be measured in each individual module. The distribution of the energies in FHCal modules is shown in figure 8 (right) for a single simulated event. Then the energies in each group of FHCal modules with the same polar angle were uniformly distributed to take into account the symmetry of these modules relative to the beam axis. The two-dimensional histogram of energy distribution in FHCal modules was fitted by a symmetrical cone, which is a linear approximation for the two-dimensional case, figure 8 (left).

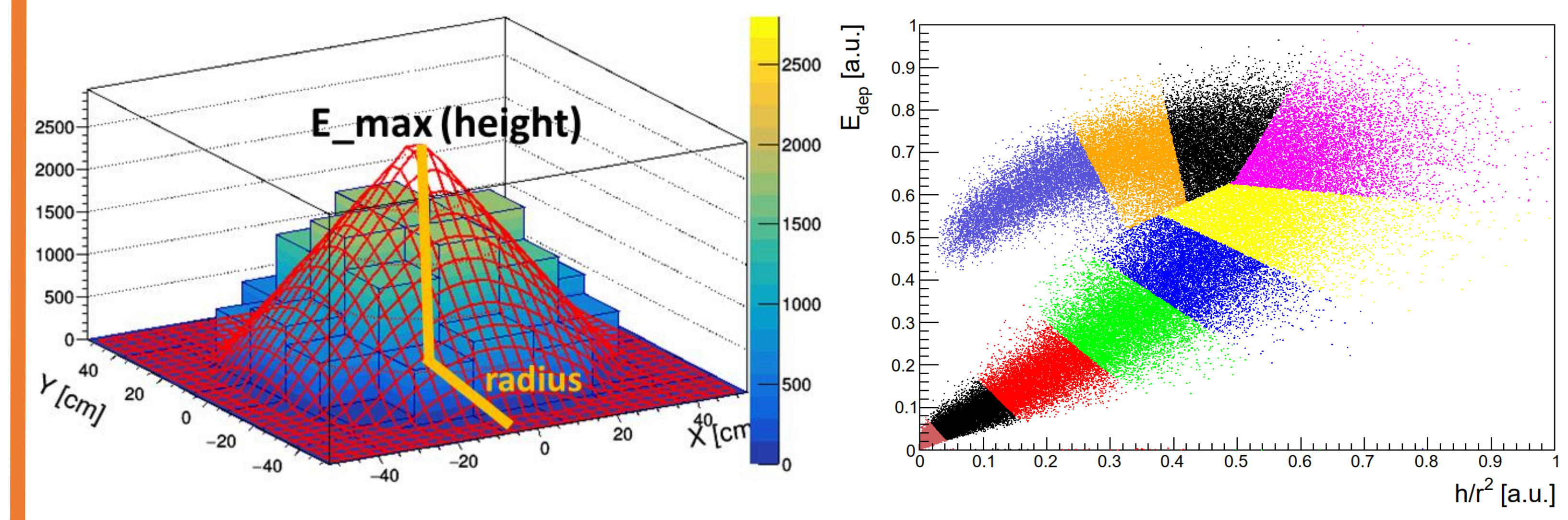

Fig.8. The correlation between the maximum energy and the deposited energy for the LAQGSM model (right) and the histogram with the two-dimensional linear fit of the energies deposited in FHCal modules (left).

The distributions of the impact parameters for each 10% group of events were fitted by the Gaussians. Figure 9 (right) represents the dependency of mean widths of the Gaussian fits on the centrality defined by 2% groups of events, respectively, for both DCM-QGSM and DCM-SMM models [3].

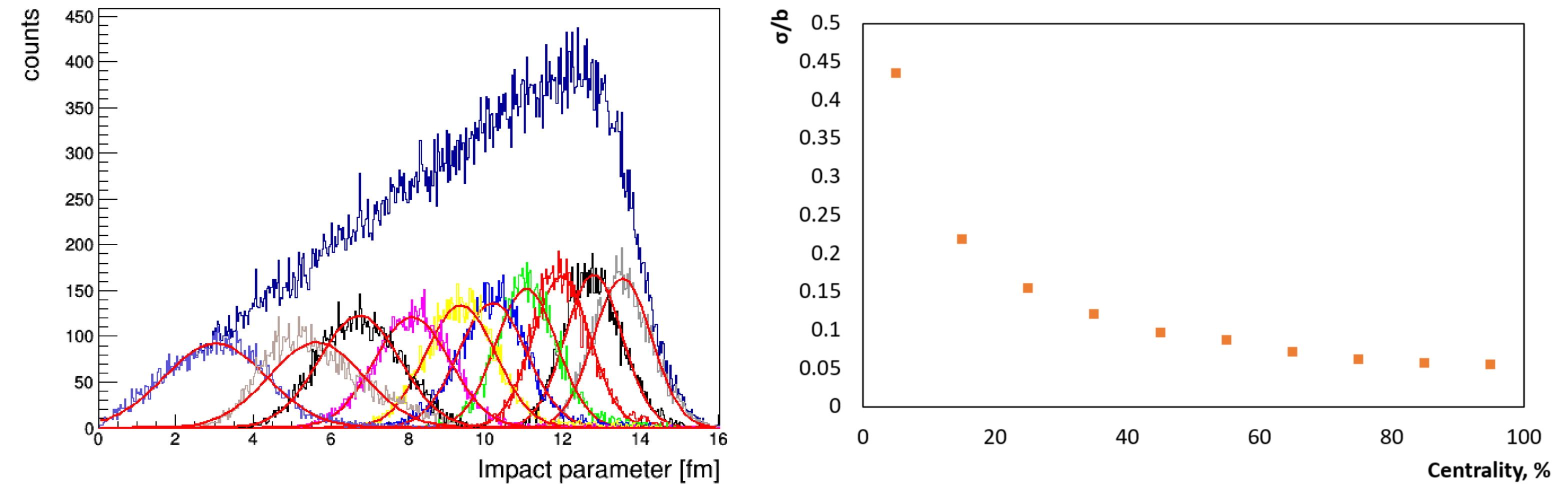

Fig. 9. Left – distributions of the impact parameters for each 10% group of events fitted by the Gaussians in the case of DCM-SMM model. Dark blue line is the impact parameter distribution for minimum bias events. Right – width of Gaussian fits of the impact parameter distributions on the centrality determined by 10% groups of events for DCM-SMM model

References:

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